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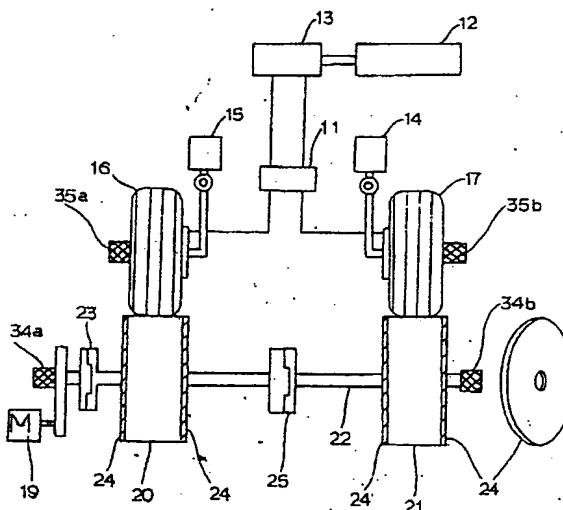
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(54) **Simulator for testing an ABS modulator**

(57) A simulator for testing an anti-lock braking system (ABS) modulator is capable of easily simulating the yawing of a vehicle and/or the disproportionate concentration of vehicle weight arising from diverse road conditions. The simulator has wheels (16, 17) rotated by compressively contacting respective flywheels (20, 21). Flywheel driving means (19, 23, 25) transmits and controls the drive forces applied to the flywheels. Rotation-speed sensors (34, 35) are provided for monitoring the rotational speeds of the wheels (16, 17) and flywheels (20, 21). Pneumatic cylinders (14, 15) are installed to respective wheels (16, 17) for regulating the frictional force between each wheel and the associated flywheel. A braking system (38) is provided for applying braking forces to the wheels in which a modulator (11) to be tested is mounted. A pneumatic pressure generating circuit (40) supplies a predetermined pressure to the braking system and the pneumatic cylinders. A controller (30) is responsive to the rotation-speed sensors (34, 35) and is arranged to control the flywheel driving means to drive the flywheels such that they have identical or different rotational speed. The controller (30) also outputs a control signal to the pneumatic pressure generating circuit (40) whereby identical or different pneumatic pressures are applied to the pneumatic cylinders (14, 15) which are connected to the wheels and operate the braking system.

FIG. 1



The present invention relates to a simulator for testing an anti-lock braking system (hereinafter simply referred to as "ABS").

Currently, in order to prevent the locking of wheels if a braking system is operated while driving a vehicle, an ABS is mounted to the vehicle, which employs a hydraulic braking system. The locking state denotes that, when a driver suddenly steps on a brake while driving, the rolling motion of the wheels is brought to a halt by the braking system mounted to the respective wheels. At this time, if the inertia force of the vehicle is so large as to exceed a frictional force between the tires and road surface, the vehicle continuously slips along the road in the travelling direction of the vehicle. Due to the slip, the frictional force is further decreased to lengthen the braking distance. In addition to this, since the frictional force is greatly decreased, the vehicle is unable to be steered, regardless of manipulation of a handle thereof, thereby possibly bringing about a disastrous accident.

In the hydraulic braking system, generally, hydraulic pressure produced while using a brake pedal is transmitted from a master cylinder to the wheel cylinders of the respective wheels. The wheel cylinder acts to decelerate the wheel speed or stop the operation of the wheel. With this action, the vehicle is decelerated or stopped. The ABS prevents the locking phenomenon to ensure the stability of straight travelling and the steering performance of the vehicle even in a situation of sudden stoppage by means of automatically controlling the braking pressure of the brake so as to completely achieve braking within the shortest possible distance. For these functions, the ABS is provided with a set of speed sensors for monitoring the speed of respective wheels, and automatically increases, decreases and maintains the hydraulic pressure of the braking in accordance with the monitored speed.

The preferable method for testing the performance of the ABS is to actually mount the ABS to a vehicle and allow the vehicle to actually travel along a road with different surface conditions, as, for instance, a dry surface, a wet surface, a frozen surface, etc. Presently, however, various kinds of vehicles are manufactured and diverse options may be added to a single vehicle type with the consequences of high costs, manpower and time to effect the performance tests of all the ABSs available on the market with respect to every kind of vehicle.

Owing to the above-described reasons, a testing apparatus capable of testing the performance of an ABS within a narrow space has been developed. For example, US Patent No. 5,101,660 discloses a dynamometer apparatus for testing two and four wheel drive vehicles under simulated road conditions. Here, the apparatus includes a front roll and a rear roll for engaging the front and rear wheels of the vehicle, an electric motor coupled to each roll, a force transducer

and a speed sensor coupled to each roll.

Almost all ABS testing apparatuses described as above are constructed to be furnished with a brake test stand, in which, under the state of mounting the ABS to an actually-used vehicle, respective wheels are placed on a pair of front-wheel driving rollers and a pair of rear-wheel driving rollers allotted to the respective front wheels and rear wheels or on pairs of driving rollers allotted to four wheels, and these pairs of driving rollers are driven to operate the ABS for testing the performance thereof. However, such a testing apparatus cannot simulate various travelling conditions, eg, the yawing of the wheels and the disproportionate concentration of the vehicle weight, making it impossible to evaluate accurate performance of the ABS. Otherwise, driving motors are supplied to respective pairs of driving rollers for driving the wheels, thereby increasing installation costs. Furthermore, most of the testing apparatuses are incorporated between the driving motor and pairs of driving rollers, with a sliding-control member, eg, an electronic clutch, for controlling a sliding characteristic between the wheels and driving roller pairs, which also induces the increase of installation costs.

It is an object of the present invention to provide a simulator for testing an ABS which reduces the problems described above.

According to a first aspect of the present invention there is provided a simulator for testing an anti-lock braking system comprising first and second rotatable wheels, first and second rotatable flywheels arranged to contact said first and second rotatable wheels, and flywheel driving means for rotating said first and second flywheels, wherein said flywheel driving means is arranged to selectively rotate said first and second flywheels at the same speed or at different speeds.

A simulator of an embodiment of the invention is able to simulate yawing of the vehicle and/or simulate a disproportionate concentration of vehicle weight on a wheel of the vehicle.

Preferably, said simulator further comprises control means for said flywheel driving means, and sensors for sensing parameters of said simulator and/or of the system under test, wherein said control means is responsive to said sensors.

For example, said control means is responsive to speed sensors monitoring the rotational speed of the or each flywheel.

In an embodiment, said simulator further comprises means for maintaining a predetermined pressure between each flywheel and the associated rotatable wheel.

Preferably, said pressure maintaining means is arranged selectively to maintain the same pressure or different pressures between each flywheel and its associated rotatable wheel.

Said simulator may further comprise braking

means for applying braking forces to said first and second rotatable wheels.

Preferably, said braking means is arranged to mount an anti-lock braking system modulator to be tested, and wherein said braking means is arranged selectively to apply the same or different braking forces to each of said rotatable wheels.

The present invention, also provides a simulator for testing an ABS modulator including rotatable opposing first and second flywheels in contact with a pair of wheels by a first predetermined pressure, and a flywheel driving portion which transfers a driving force to the first and second flywheels, and manages (controls the transfer and stoppage of) the driving force with respect to the first and second flywheels and/or the driving force with respect to the second flywheel. Furthermore, wheel rotation-speed sensors monitor the rotational speed of the pair of wheels, and flywheel rotation-speed sensors monitor the rotational speed of the first and second flywheels. A wheel pressing unit respectively installed to the pair of wheels maintains a contact pressure between the wheel and flywheel by the predetermined pressure to allow a frictional force between the wheel and flywheel to concur with a frictional force between a tire and a road surface. A braking system generates a second predetermined pressure equivalent to the pressure induced by a driver stepping on a brake pedal, generates a braking force corresponding to the second predetermined pressure, transfers the braking force to the wheels, and then mounts a modulator to be tested thereon. A pneumatic pressure generator supplies the second predetermined pressure to the braking system and wheel pressing unit, and a controller electrically connected to the flywheel driving portion, wheel rotation-speed sensors, flywheel rotation-speed sensors, and pneumatic pressure generator, simulates various road surface conditions in accordance with a command, controls the flywheel driving portion to allow the pair of flywheels to have an identical rotational speed or different rotational speeds in response to an input signal from the flywheel rotation-speed sensors, supplies a control signal to the pneumatic pressure generator to provide an identical rotational speed or different rotational speeds to the wheel pressing unit respectively connected to the pair of wheels, and outputs a control signal to the pneumatic pressure generator to operate the braking system.

The flywheel driving portion may comprise a motor for generating the driving force, a driving shaft forming a rotational shaft of the first and second flywheels for transferring the driving force from the motor to the first and second flywheels, first driving force managing means provided on the driving shaft between the motor and first flywheel for managing the transfer of the driving force, and second driving force managing means provided on the driving shaft be-

tween the first and second flywheels for managing the transfer of the driving force to the second flywheel.

As to the first and second driving force managing means, an electromagnetic clutch may be employed.

As to the wheel pressing means, pneumatic cylinders may be employed.

As to the rotation-speed sensors, encoders for generating electrical pulses in response to the rotation of the wheels and flywheels may be employed.

The pneumatic pressure generating circuit may comprise a pneumatic pressure generating portion, a braking pressure supply portion for supplying the second predetermined pneumatic pressure to the braking pressure generating means, and first and second pneumatic pressure supply portions for independently supplying the first predetermined pneumatic pressure to the respective wheel pressing means, wherein the first pneumatic pressure supply portions and braking pressure supply portion are respectively formed of a pneumatic regulator for regulating the pneumatic pressure from the pneumatic pressure generating portion in a predetermined level, a flux controller for controlling flux, and a solenoid valve connected between the pneumatic regulator and a flux controller for switching a path for receiving the pneumatic pressure, and the other of the first and second pneumatic pressure supply portions is formed of a first solenoid valve connected to the pneumatic pressure generating portion for switching the path for receiving the pneumatic pressure, a second solenoid valve connected to the first solenoid valve for switching the pneumatic path of high level or low level, a high-level pneumatic regulator connected to the second solenoid valve for controlling the pneumatic pressure for supplying the pneumatic pressure of high level to the wheel pressing means connected to the other pneumatic supply portion, a low-level pneumatic regulator connected to the second solenoid valve for controlling the pneumatic pressure for supplying the pneumatic pressure of low level to the wheel pressing means connected to the other pneumatic supply portion, a shuttle valve for opening/closing the outputs from the high-level pneumatic regulator and low-level pneumatic regulator, an exhaust solenoid valve for discharging air when the supplied pneumatic pressure is changed from high level to low level, a timer, and a flux controller for controlling flux.

The simulator for testing an ABS modulator according to the invention may further comprise at least one inertia plate detachably fixed to the flywheel to generate the inertia moment identical to the inertia moment of a vehicle weight.

The braking means comprises braking pressure generating means for supplying the pressure equivalent to the pressure caused by the driver stepping on the brake pedal, a master cylinder for generating a hydraulic pressure for braking the pair of wheels in ac-

cordance with the pressure from the braking pressure generating means, and a brake provided to the respective pair of wheels, and the modulator is supplied between the brake and master cylinder.

The braking pressure generating means may be formed of a pneumatic cylinder.

A simulator according to the present invention constructed as above is provided with one driving motor and two electronic clutches to economise installation cost over a conventional testing apparatus including four driving motors and four electronic clutches. Also, by altering the inertia moment of the flywheels and the pressure of the wheels against the flywheels, the yawing of vehicles and the disproportionate concentration of the vehicle weight can be simulated under the various vehicle weight to enable the testing of the ABS modulator by setting diverse road surface conditions.

Embodiments of the present invention will hereinafter be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows schematically the overall structure of a simulator for testing an ABS modulator of one embodiment of the present invention;

Figure 2 is a schematic block diagram illustrating the simulator of Figure 1; and

Figure 3 shows one embodiment of a pneumatic circuit connected to the first, second and third pneumatic cylinders shown in Figures 1 and 2.

Figures 1 to 3 show a simulator for testing an ABS modulator, the simulator having first and second flywheels 20 and 21 which are in rotational contact with a pair of wheels 16 and 17 by a predetermined pressure. The first and second flywheels 20 and 21 are provided with a flywheel driving portion for transmitting a driving force to the first and second flywheels 20 and 21 and for interrupting the driving force with respect to the first and second flywheels 20 and 21 and/or the second flywheel 21. The flywheel driving portion has an electric motor 19, and a driving shaft 22 for transferring the driving force generated from the electric motor 19 to the first and second flywheels 20 and 21 while constituting a rotational shaft of the first and second flywheels 20 and 21. A first electronic clutch 23 is installed on the driving shaft 22 between the electric motor 19 and the first flywheel 20, and a second electronic clutch 25 for managing the driving force transferred to the second flywheel 21 is installed on the driving shaft 22 between the first and second flywheels 20 and 21.

The simulator according to one embodiment of the present invention includes a braking system 38 arranged to generate a pressure which is equivalent to the pressure produced by a driver stepping on a brake pedal. The braking system 38 induces a braking force in response to the pressure generated and transmits the braking force to the pair of wheels 16 and 17. The braking system 38 is further provided with a first

pneumatic cylinder 12 and a master cylinder 13. Reference numeral 11 denotes an ABS modulator to be tested. The ABS modulator 11 is installed between the master cylinder 13 of the braking system 38 in a vehicle and a wheel cylinder (not shown) attached to the pair of wheels 16 and 17 to regulate the hydraulic pressure supplied to the braking system 38. Manual braking is performed by directly driving a piston of the master cylinder 13 by means of the first pneumatic cylinder 12. A pneumatic pressure generated by a pneumatic circuit 40 illustrated in Figure 3 is partially supplied to the first pneumatic cylinder 12. By this pneumatic pressure, the hydraulic pressure to be supplied to the braking system 38 is generated from the master cylinder 13. The pneumatic pressure is equivalent to the pressure obtained by a driver stepping on the brake pedal.

The other pneumatic pressure generated by pneumatic circuit 40 is supplied to a second pneumatic cylinder 14 and a third pneumatic cylinder 15 which are wheel pressing apparatus. In order to force the frictional force between the pair of wheels 16 and 17 and the pair of flywheels 20 and 21 to correspond to the frictional force between a tire and a road surface during actual travelling, the wheel pressing apparatus is provided to the pair of wheels 16 and 17 for maintaining a contact pressure between the wheels 16 and 17 and the pair of flywheels 20 and 21 by a predetermined pressure. The second and third pneumatic cylinders 14 and 15 are mechanically connected to opposing first and second wheels 16 and 17. The pneumatic pressure is set to have a pressure value determined by considering the frictional force between the tire and road surface, which is supplied to the first and second wheels 16 and 17. The frictional force generally exerted on the wheel is produced proportional to a frictional coefficient between the wheel and road surface and a perpendicular contact force by the vehicle weight. Thus, in order to apply the frictional force variation in accordance with diverse road surface conditions possibly appearing in the actual situation, the frictional coefficient is not varied but the pressures produced by the second and third pneumatic cylinders 14 and 15 are applied to the first and second wheels 16 and 17 for varying the perpendicular contact force between the first and second wheels 16 and 17 and the first and second flywheels 20 and 21 in the simulator. Additionally, the pressure can be differently set to the second and third pneumatic cylinders 14 and 15 in the simulator for simulating circumstances in which a disproportionate concentration of the vehicle weight is applied to one wheel, caused for example, in actual travel of the vehicle whilst travelling along uneven road surfaces or curved roads.

The first and second flywheels 20 and 21 function as travelling surfaces of the vehicle in actual travel, contact the first and second wheels 16 and 17 by

a predetermined pressure, and are rotated by the rotation of the driving shaft 22 fixed to the first and second flywheels 20 and 21. The driving shaft 22 is rotated by the electric motor 19. In other words, the rotational force originating from the electric motor 19 is transferred to the first and second wheels 16 and 17 via the driving shaft 22 and the first and second flywheels 20 and 21 to rotate the first and second wheels 16 and 17. A decelerator may be installed between the electric motor 19 and the driving shaft 22 for permitting first and second flywheels 20 and 21 to be rotated by a predetermined number of revolutions.

To apply the inertia moment of the vehicle varied by the weight and speed of the vehicle during actual travel to the simulator, the size and weight of the first and second flywheels 20 and 21 are determined such that the inertia moment of the flywheel corresponds to the inertia moment of the actual vehicle. Also, at least one inertia plate 24 may be detachably mounted to the first and second flywheels 20 and 21 to enable the testing of the ABS modulator with respect to various kinds of vehicles having different weights. At this time, the number of inertia plates to be mounted is determined by considering the inertia moment of the vehicle proportional to the weight of the actual vehicle to which the ABS modulator to be tested is mounted.

The first electronic clutch 23 is installed onto the driving shaft 22 between the electric motor 19 and the first flywheel 20, and the second electronic clutch 25 is installed onto the driving shaft 22 between the first and second flywheels 20 and 21. The first and second electromagnetic clutches 23 and 25 are under normally connected status to each other to transfer the driving force of the electric motor 19 to the first and second flywheels 20 and 21. Once the number of revolutions of the first and second flywheels 20 and 21 reaches a predetermined number of revolutions, the first electromagnetic clutch 23 is opened to initiate the operation of the brake under the state that the electric motor 19 and the first and second flywheels 20 and 21 are separated. The second electromagnetic clutch 25 serves to manage the driving force from the electric motor 19 to independently rotate the first and second flywheels 20 and 21.

The simulator according to one embodiment of the present invention is provided with four speed sensors, ie, the first and second flywheel-speed sensors 34a and 34b and the first and second wheel-speed sensors 35a and 35b, to independently monitor respective rotational speeds of the first and second flywheels 20 and 21 and of the first and second wheels 16 and 17 respectively. Although an encoder is employed in this embodiment, any element such as a tachogenerator capable of detecting the rotational speed may be used.

Figure 2 is a block diagram of the simulator for testing the ABS modulator shown in Figure 1. The overall operation of the simulator is controlled by a

programmable logic controller (hereinafter referred to as "PLC") 30. An input port of the PLC 30 is connected to the first and second flywheel-speed sensors 34a and 34b and the first and second wheel-speed sensors 35a and 35b, and an output port thereof is connected to a flywheel driving portion 32, first electromagnetic clutch 23, second electromagnetic clutch 25, an output unit 36 and a pneumatic circuit 40. Figure 3 is a detailed circuit diagram of the pneumatic circuit 40 shown in Figure 2.

Referring to Figures 2 and 3, the operation of the simulator according to the present invention will be described in detail.

After the ABS modulator to be tested is connected between the master cylinder 13 and the wheel cylinder of the simulator, electric power is supplied to the simulator. Then, the test conditions, eg, set values of the rotational speed of the first and second flywheels 20 and 21, the braking pressure produced by the first pneumatic cylinder 12 for driving the master cylinder 13, and the pneumatic pressure of the second and third pneumatic cylinders 14 and 15, are supplied via the input panel of PLC 30. Thereafter, inertia plate 24 in proper numbers is mounted to the flywheel to force the inertia moment of the vehicle created by the weight of the vehicle to which the ABS modulator is actually mounted to concur with the inertia moment of the first and second flywheels 20 and 21.

An air-compressor driving signal from PLC 30 is supplied into an air-compressor driver 37 to drive an air compressor 39 which can be automatically driven by PLC 30, or manually driven as required. After driving air compressor 39, a valve switching signal is supplied from PLC 30 to second, third and fourth solenoid valves 46, 48 and 49 to switch them, so that the pneumatic pressure produced from the air compressor 39 is transferred to the second and third pneumatic cylinders 14 and 15. By the pneumatic pressure transferred to the second and third pneumatic cylinders 14 and 15, the first and second flywheels 20 and 21, and the first and second wheels 16 and 17 come into contact with one another with a predetermined contact pressure.

In order to simulate the disproportionate concentration of the vehicle weight occurring when a vehicle moves along uneven portions of road or travels along a curved road, the simulator may supply pneumatic pressure at a low level, lower than that of the second pneumatic cylinder 14, to the third pneumatic cylinder 15. For this operation, under the state that a predetermined pneumatic pressure is supplied to the third and fourth solenoid valves 48 and 49 as described above, the valve switching signal transferred from PLC 30 to the third and fourth solenoid valves 48 and 49 is turned off, and the valve switching signal is output to an exhaust solenoid valve 54. By doing so, air is discharged via exhaust solenoid valve 54 during the time preset by a timer 53 to change the pneumatic

pressure of the third pneumatic cylinder 13 from high level to low level.

An electric-motor driving signal from PLC 30 is supplied into flywheel driving portion 32 to rotate the electric motor 19 shown in Figure 1. Upon rotation of the electric motor 19, the driving shaft 22 and the first and second flywheels 20 and 21 operatively connected to the electric motor 19 are rotated to rotate the first and second wheels 16 and 17 contacting the first and second flywheels 20 and 21 with a predetermined contact pressure.

If the rotational speed of the first and second flywheels 20 and 21 monitored by the flywheel-speed sensor 34 reaches a predetermined value, a first clutch separation signal is output from PLC 30 to the first electromagnetic clutch 23 to shift the first electromagnetic clutch 23 from the connection state to the separation state.

For the purpose of simulating the situation that, in actual travel, one wheel of the vehicle contacts a road having a freezing or wet surface which has a different frictional coefficient from that of the other wheel, the rotational speed of individual ones of the first and second flywheels 20 and 21 may be independently set in the simulator. In this case, when the rotational speed of the first and second flywheels 20 and 21 reaches a second rotational speed slower than a first rotational speed, the second electromagnetic clutch 25 is primarily shifted to the separation state by a second clutch separation signal from PLC 30. After this, when the rotational speed of the first flywheel 20 attains the first rotational speed, the first electromagnetic clutch 23 is shifted to the separation state by the first clutch separation signal from PLC 30. With this operation, the driving force from the electric motor 19 is not transmitted to the driving shaft 22, and, under this circumstance, the braking system 38 begins to operate.

A braking pressure equivalent to the pressure with which a driver manipulates the brake pedal is generated from the first pneumatic cylinder 12 and directly supplied to the piston of the master cylinder 13, thereby operating the braking system 38. More specifically, once the valve switching signal is output from PLC 30 to the first solenoid valve 43 to switch the first solenoid valve 43, the pneumatic pressure of a predetermined pressure is provided to the first pneumatic cylinder 12. With the pneumatic pressure supplied to the first pneumatic cylinder 12, the braking pressure is transferred to the master cylinder 13 to operate the braking system 38. The magnitude of the braking pressure is regulated by a second pneumatic regulator 42 by a certain pressure. The time taken for elevating the braking pressure results from the time required for operating the first solenoid valve 43 and the time delay required until the pressure is formed within the first pneumatic cylinder 12. This braking pressure rising time corresponds to the time

delay until the driver steps on the brake pedal in an actual situation.

Braking system 38, like a general ABS-mounted braking system, includes a brake consisting of the master cylinder 13, the ABS modulator 11, the wheel cylinder, a brake disc and a friction pad. The braking pressure in response to the actual manipulation of the brake pedal of the vehicle is generated from the first pneumatic cylinder 12 and supplied to the master cylinder 13, and the hydraulic pressure from the master cylinder 13 is supplied to the wheel cylinder via ABS modulator 11, so that the wheel cylinder presses the friction pad towards the brake disc to effect braking.

To analyse the operational performance of the ABS modulator 11 while braking, predetermined data such as the speed of the first and second wheels 16 and 17 monitored by the first and second wheel-speed sensors 35a and 35b, the speed of the first and second flywheels 20 and 21 corresponding to the vehicle speed monitored by the first and second flywheel-speed sensors 34a and 34b, the pressure of brake callipers, and the pressure of the master cylinder 13 is supplied to a display unit or output unit 36 which is the printing means. At this time, the predetermined data is input to a computer via an interface to carry out data processing, output and the like.

Referring to Figure 3, the operation of the braking system 38 will be described in detail. As described above, the pneumatic circuit 40 functions as means affording the predetermined braking pressure to the master cylinder 13 in accordance with a control signal of PLC 30, and providing the perpendicular contact force of the first and second wheels 16 and 17 against the first and second flywheels 20 and 21.

As shown in the drawing, the pneumatic pressure from the air compressor 39 passes through a first pneumatic regulator 41 prior to being supplied to a first pneumatic cylinder 12 via second pneumatic regulator 42, the first solenoid valve 43 and a flux controller 44 to produce the hydraulic pressure to master cylinder 13 shown in Figure 1 which is connected to the piston of the first pneumatic cylinder 12, thereby accomplishing the braking.

The pneumatic pressure from the first pneumatic regulator 41 is also supplied to second pneumatic cylinder 14 via a third pneumatic regulator 45, the second solenoid valve 46 and a flux controller 47. Therefore, the perpendicular contact force equivalent to the frictional force between the wheel and the ground surface during the actual travelling is generated between the wheel 17 and the flywheel 21.

Meantime, for the purpose of simulating a situation in which the vehicle weight disproportionately concentrates on one wheel when the vehicle actually moves along the uneven portion of a road or along a curved road, it is necessary to supply a pneumatic pressure different from that of the second pneumatic cylinder 14 to the third pneumatic cylinder 15. In more

detail, when vehicle weight is proportionately placed, to provide the pneumatic pressure of a high level identical to that of the second pneumatic cylinder 14 to the third pneumatic cylinder 15, the pneumatic pressure from the first pneumatic regulator 41 is supplied to the third pneumatic regulator 15 via third solenoid valve 48, fourth solenoid valve 49, a fourth pneumatic regulator 50 for regulating the pneumatic pressure to high level, a shuttle valve 52 for selectively opening/closing an output side path of fourth and fifth pneumatic regulators 50 and 51, and a flux controller 55. For simulating a situation in which the vehicle weight disproportionately concentrates on the second wheel 17, the pneumatic pressure of a low level, lower than that of the second pneumatic cylinder 14, should be supplied to the third pneumatic cylinder 15. For this operation, the valve switching signal from PLC 30 to third and fourth solenoid valves 48 and 49 is turned off to shift the valve position of the third and fourth solenoid valves 48 and 49. Following this operation, the pneumatic pressure from the first pneumatic regulator 41 is supplied to the fifth regulator 51 for regulating the pneumatic pressure to the low level, and exhaust solenoid valve 54 is open for the time set by timer 53, so that the pneumatic pressure of the low level, lower than that supplied to the second pneumatic cylinder 14, is provided to the third pneumatic cylinder 15. Consequently, the braking performance of the ABS modulator 11 can be analysed with respect to the situations in which the vehicle weight disproportionately or proportionately concentrates on one wheel.

On the other hand, the pneumatic circuit utilised in the simulator is not limited to the pneumatic circuit shown in Figure 3, but any type capable of performing the above-stated operation may be utilized.

A simulator as described and illustrated which has a single driving motor and two electromagnetic clutches can reduce installation costs as compared with the conventional testing apparatus which has four driving motors and four electromagnetic clutches. In addition, the inertia moment of the flywheel is variable by means of the proper number of inertia plates, enabling the performance testing of the ABS with respect to diverse kinds of vehicles. Moreover, since the second and third pneumatic cylinders are employed to identically or differently set the pressure supplied to the pair of flywheels corresponding to the pair of wheels, the yawing of the vehicle and disproportionate concentration of the vehicle weight can be simulated. As a result, the ABS modulator can be tested by setting various road surface conditions to facilitate the comparison of the objective performance with respect to various ABSs available on the market.

While the present invention has been particularly shown and described with reference to particular embodiments thereof, it will be understood by those skilled in the art that various changes in form and details

may be made without departing from the scope of the invention as defined in the appended claims.

## Claims

1. A simulator for testing an anti-lock braking system comprising first and second rotatable wheels, first and second rotatable flywheels arranged to contact said first and second rotatable wheels, and flywheel driving means for rotating said first and second flywheels, wherein said flywheel driving means is arranged to selectively rotate said first and second flywheels at the same speed or at different speeds.
2. A simulator as claimed in claim 1, further comprising control means for said flywheel driving means, and sensors for sensing parameters of said simulator and/or of the system under test, wherein said control means is responsive to said sensors.
3. A simulator as claimed in claim 2, wherein said control means is responsive to speed sensors monitoring the rotational speed of the or each flywheel.
4. A simulator as claimed in any preceding claim, further comprising means for maintaining a predetermined pressure between each flywheel and the associated rotatable wheel.
5. A simulator as claimed in claim 4, wherein said pressure maintaining means is arranged selectively to maintain the same pressure or different pressures between each flywheel and its associated rotatable wheel.
6. A simulator as claimed in any preceding claim, further comprising braking means for applying braking forces to said first and second rotatable wheels.
7. A simulator as claimed in claim 6, wherein said braking means is arranged to mount an anti-lock braking system modulator to be tested, and wherein said braking means is arranged selectively to apply the same or different braking forces to each of said rotatable wheels.
8. A simulator for testing an anti-lock braking system modulator comprising:
  - rotationally opposing first and second flywheels in contact with a pair of wheels by a first predetermined pressure;
  - a flywheel driving portion for transferring a driving force to said first and second flywheels,

and managing the driving force with respect to said first and second flywheels and/or the driving force with respect to said second flywheel;

wheel rotation-speed sensors for monitoring the rotational speed of said pair of wheels;

flywheel rotation-speed sensors for monitoring the rotational speed of said first and second flywheels;

wheel pressing means respectively installed to said pair of wheels for maintaining a contact pressure between said wheel and flywheel by the first predetermined pressure to allow a frictional force between said wheel and flywheel to concur with a frictional force between a tire and a road surface;

braking means for generating a second predetermined pressure equivalent to a pressure induced by a driver stepping on a brake pedal, generating a braking force corresponding to said second predetermined pressure, transferring said braking force to said wheels, and mounting a modulator to be tested;

a pneumatic pressure generating circuit part for supplying the second predetermined pressure to said braking means and wheel pressing means; and

controlling means electrically connected to said flywheel driving portion, wheel rotation-speed sensors, flywheel rotation-speed sensors, and pneumatic pressure generating circuit part for simulating various road surface conditions in accordance with a command, controlling said flywheel driving portion to allow said pair of flywheels to have an identical rotational speed or different rotational speeds in response to an input signal from said flywheel rotation-speed sensors, supplying a control signal to said pneumatic pressure generating circuit part to provide an identical rotational speed or different rotational speeds to said wheel pressing means respectively connected to said pair of wheels, and outputting a control signal to said pneumatic pressure generating circuit part to operate said braking means.

9. A simulator for testing an anti-lock braking system modulator as claimed in any preceding claim, wherein said flywheel driving portion comprises:

a motor for generating the driving force;

a driving shaft for forming a rotational shaft of said first and second flywheels and for transferring said driving force from said motor to said first and second flywheels;

first driving force managing means provided on said driving shaft between said motor and first flywheel for managing the transfer of said driving force; and

second driving force managing means provided on said driving shaft between said first and

second flywheels for managing the transfer of said driving force to said second flywheel.

10. A simulator for testing an anti-lock braking system modulator as claimed in claim 8, wherein said pneumatic pressure generating circuit part comprises a pneumatic pressure generating portion, a braking pressure supply portion for supplying the second predetermined pneumatic pressure to said braking pressure generating means, and first and second pneumatic pressure supply portions for independently supplying the first predetermined pneumatic pressure to respective wheel pressing means,

wherein said first pneumatic pressure supply portion and braking pressure supply portion are respectively comprised of a pneumatic regulator for regulating the pneumatic pressure from said pneumatic pressure generating portion in a predetermined level, a flux controller for controlling flux, and a solenoid valve connected between said pneumatic regulator and flux controller for switching a path for receiving said pneumatic pressure, and

said second pneumatic pressure supply portion is comprised of a first solenoid valve connected to said pneumatic pressure generating portion for switching said path for receiving said pneumatic pressure, a second solenoid valve connected to said first solenoid valve for switching the pneumatic path of high level or low level, a high-level pneumatic regulator connected to said second solenoid valve for controlling said pneumatic pressure for supplying the pneumatic pressure of high level to said wheel pressing means connected to said other pneumatic supply portion, a low-level pneumatic regulator connected to said second solenoid valve for controlling said pneumatic pressure for supplying the pneumatic pressure of low level to said wheel pressing means connected to said other pneumatic supply portion, a shuttle valve for opening/closing the outputs from said high-level pneumatic regulator and low-level pneumatic regulator, an exhaust solenoid valve for discharging air when the supplied pneumatic pressure is changed from high level to low level, a timer, and a flux controller for controlling flux.





FIG. 2

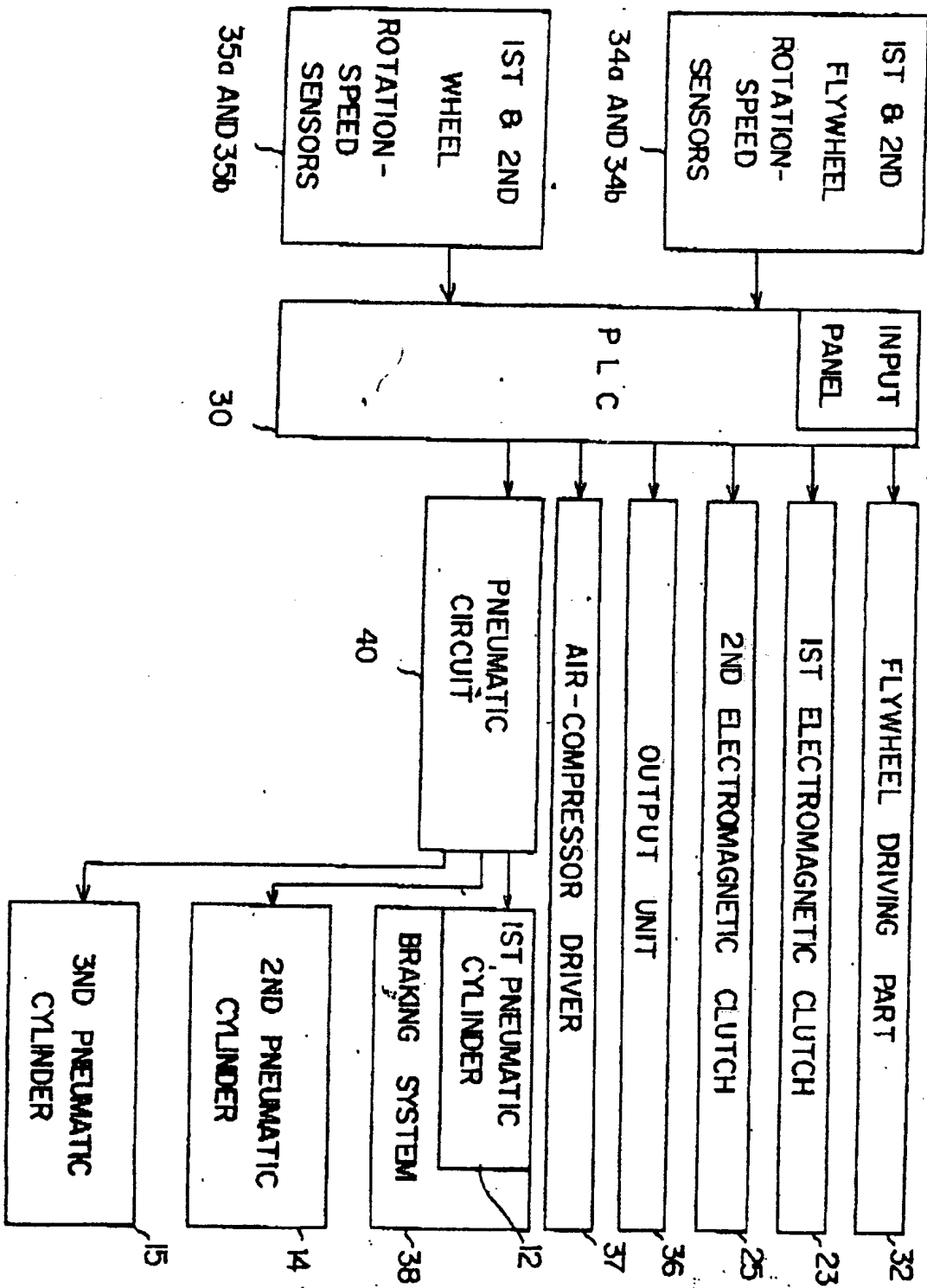
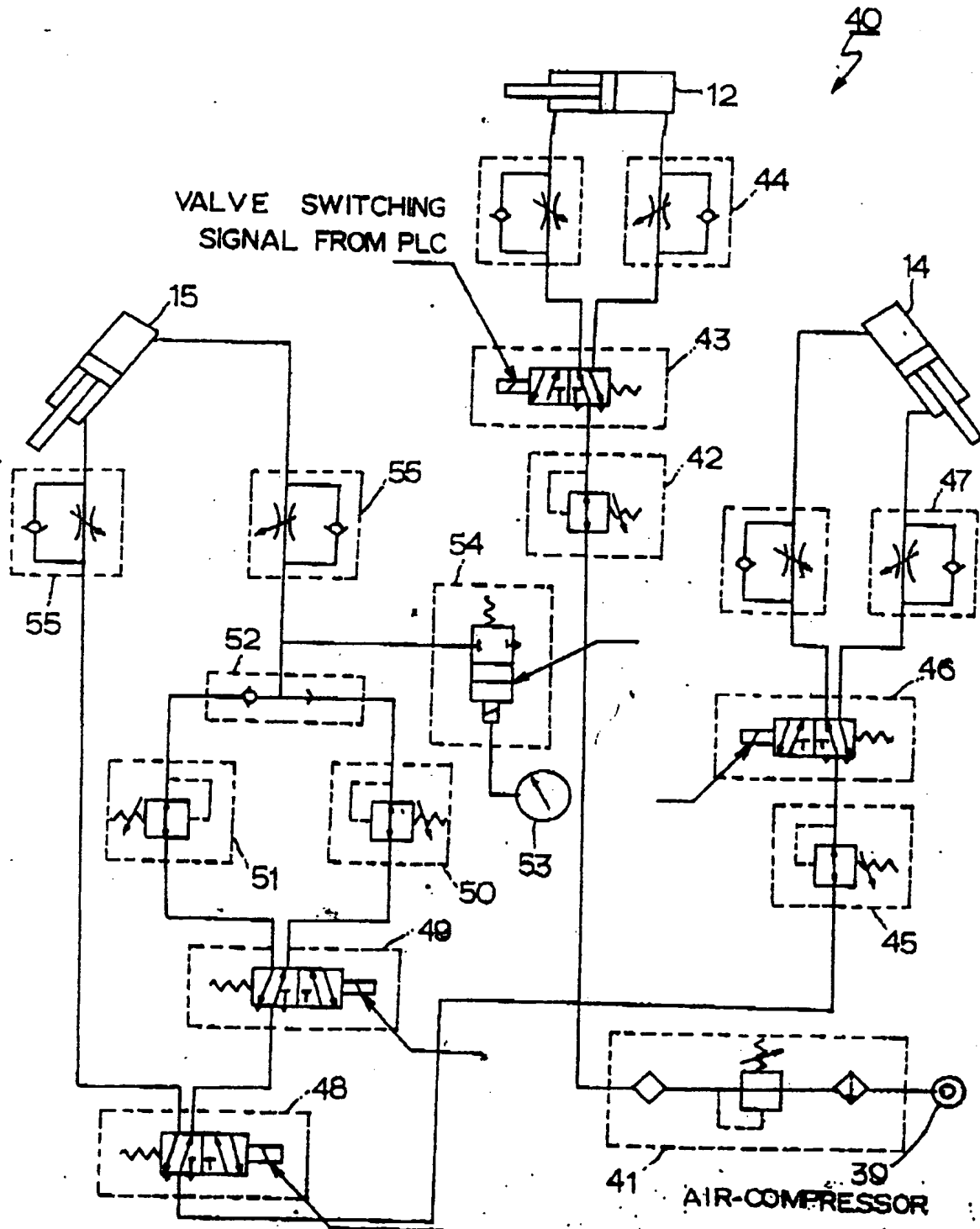
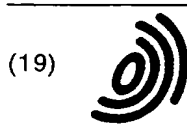


FIG. 3



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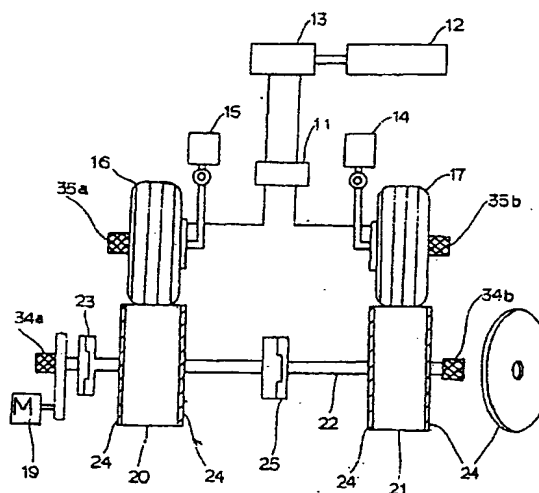
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(54) **Simulator for testing an ABS modulator**

(57) A simulator for testing an anti-lock braking system (ABS) modulator is capable of easily simulating the yawing of a vehicle and/or the disproportionate concentration of vehicle weight arising from diverse road conditions. The simulator has wheels (16, 17) rotated by compressively contacting respective flywheels (20, 21). Flywheel driving means (19, 23, 25) transmits and controls the drive forces applied to the flywheels. Rotation-speed sensors (34, 35) are provided for monitoring the rotational speeds of the wheels (16, 17) and flywheels (20, 21). Pneumatic cylinders (14, 15) are installed to respective wheels (16, 17) for regulating the frictional force between each wheel and the associated flywheel. A braking system (38) is provided for applying braking forces to the wheels in which a modulator (11) to be tested is mounted. A pneumatic pressure generating circuit (40) supplies a predetermined pressure to the braking system and the pneumatic cylinders. A controller (30) is responsive to the rotation-speed sensors (34, 35) and is arranged to control the flywheel driving means to drive the flywheels such that they have identical or different rotational speed. The controller (30) also outputs a control signal to the pneumatic pressure generating circuit (40) whereby identical or different pneumatic pressures are applied to the pneumatic cylinders (14, 15) which are connected to the wheels and operate the braking system.

FIG. 1



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# EUROPEAN SEARCH REPORT

Application Number  
EP 95 30 4395

| DOCUMENTS CONSIDERED TO BE RELEVANT  |   |  |  |
|--|---|--|--|
| Category   | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim                                | CLASSIFICATION OF THE APPLICATION (Int.Cl.6) |
| D,A  | EP-A-0 507 631 (CLAYTON IND) 7 October 1992<br>* the whole document *         | 1-10   | G01L5/28<br>G01M17/00                        |
| A  | DE-A-40 28 561 (IVECO MAGIRUS) 12 March 1992<br>* the whole document *        | 1-10   |  |
| A  | US-A-3 905 225 (MOSS, DECEASED ET AL.)<br>* the whole document *              | 1-10   |  |
|  |   |  | TECHNICAL FIELDS SEARCHED (Int.Cl.6)         |
|  |   |  | G01L<br>G01M                                 |
| The present search report has been drawn up for all claims   |   |  |  |
| Place of search<br>THE HAGUE   |   | Date of completion of the search<br>2 April 1996 | Examiner<br>Mucs, A                          |
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